

Project Horizon — a wake-up call



Research into the effects of sleepiness on the cognitive performance of maritime watchkeepers under different watch patterns, using ships' bridge, engine and liquid cargo handling simulators.



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What is Project Horizon?

Project Horizon is a major multi-partner European research study that brought together 11 academic institutions and shipping industry organisations with the agreed aim of delivering empirical data to provide a better understanding of the way in which watchkeeping patterns can affect the sleepiness levels of ships' watchkeepers.

Why was it set up?

The project was established to:

- **define and undertake scientific methods for measurement of fatigue in various realistic seagoing scenarios using bridge, engineroom and cargo simulators**
- **determine the effects of watch systems and components of watch systems on fatigue**
- **capture empirical data on the cognitive performance of watchkeepers working within those realistic scenarios**
- **assess the impact of fatigue on decision-making performance**
- **develop a tool for evaluating potential fatigue risk of different watch systems using mathematical models.**
- **determine arrangements for minimising risks to ships and their cargoes, seafarers, passengers and the marine environment**

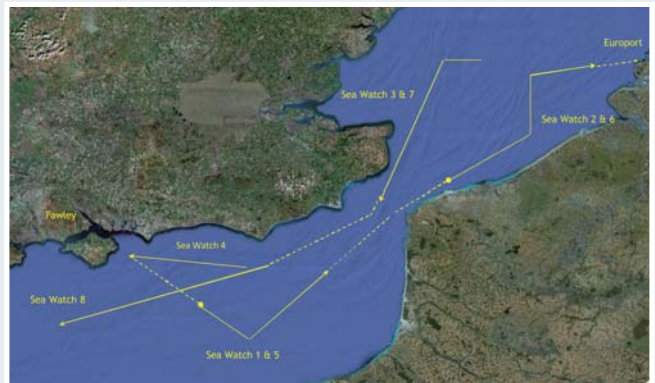
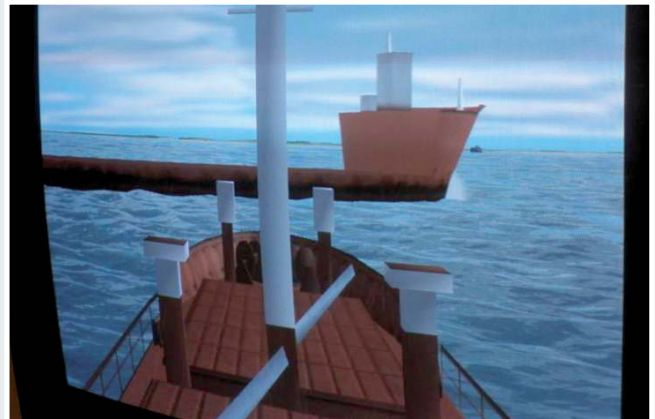
How did it work?

At the heart of the project was the extensive use of ship simulators in Sweden and the UK to examine the decision-making and cognitive performance of officers during a range of real-life, real-time scenarios of voyage, workload and interruptions. A total of 90 experienced deck and engineer officer volunteers participated in rigorous tests at Chalmers University of Technology in Göteborg, and at Warsash Maritime Academy (WMA) at Southampton Solent University to measure their levels of sleepiness and performance during seagoing and port-based operations on bridge, engine and liquid cargo handling simulators.

The project sought to take understanding of the issues to a new level with specialist input from some world-leading transport and stress research experts. Academic experts at WMA, Chalmers and the Stress Research Institute at Stockholm University (SRI) devised the simulator scenarios, setting the requirements for

fatigue measurement and determining performance degradation measures for watchkeepers, and SRI analysed the results from the week-long programmes.

Finally, in response to the research findings, the Project Horizon partners have developed a fatigue management toolkit for the industry, which seeks to provide guidance to owners, operators, maritime regulators and seafarers to assist them in organising work patterns at sea in the safest and healthiest way possible.



What is fatigue and is it different from sleepiness?

Fatigue is commonly described as a state of physical and/or mental exhaustion that can be caused by a wide range of factors, including long hours, shift work, inadequate rest and international travel. It can result in a progressive decline in alertness and performance, a loss of energy and slowed movements and reactions.

Although sleepiness is often used to describe the state of fatigue, it is generally defined separately as a specific state in which an individual is struggling to maintain wakefulness.

Laboratory research and studies in other transport modes have demonstrated that severe sleepiness (and even sleep onset) and performance deterioration is common amongst workers undertaking night shifts.



Fatigue is also an important health issue, with significant evidence to show the way in which long-term sleep loss can be a risk factor in such conditions as obesity, cardiovascular disease and diabetes.

Why is fatigue an important issue for shipping?

Shipping is the ultimate 24/7 industry. Inherently globalised in its nature, the industry is complex, capital-intensive, increasingly technologically sophisticated and of immense economic and environmental significance. More than 80% of world trade moves by sea, almost 90% of EU external freight trade is seaborne, and some 40% of intra-EU freight is carried by shortsea shipping. Around 40% of the world fleet is beneficially controlled in the EEA, and EU-registered tonnage accounts for more than 20% of the world total. On average, around four million passengers embark and disembark in EU27 ports every year – the vast majority being carried by ferries.

The increasingly intensive nature of shipping operations means that seafarers frequently work long and irregular hours. And factors such as noise, vibration, sailing patterns, port calls, cargo handling and other activities can all reduce the ability of seafarers to gain quality sleep during their rest periods.

Seafarers are already usually covered by company, sector-specific, flag state or IMO rules banning or severely restricting alcohol use at sea. Studies have shown that around 22 hours of wakefulness will have a similar effect upon the impairment of an individual's performance as a blood-alcohol concentration of 0.10% -- double the legal driving limit in most EU member states.

Is there evidence of safety problems?

The role of fatigue and sleepiness in other safety-critical industries and in other modes of transport has been extensively researched. In contrast, there has been very little shipping-based research and studies of seafarers' working hours and it has been largely over the past 20 years that an increasing weight of evidence gathered from research among seafarers and analysis of the role of fatigue in accidents at sea has begun to emerge.

Project Horizon was established in response to growing concern about the increased evidence of the role of fatigue and sleepiness in maritime accidents. The project is therefore closely aligned to the FP7 (Sustainable Surface Transport 2008 RTD-1 call) aims of increased safety and security, and reduced fatalities.

Over the past 20 years, the shipping industry has become increasingly aware of the importance of the 'human factor' in safe shipping operations. The increased complexity of ships' systems and the growing technological sophistication

of onboard equipment have placed greater emphasis on the performance of seafarers – and watchkeepers in particular. The marked increase in the size of passenger ships and cargo vessels has also highlighted the potential for substantial loss of life or pollution in the event of an accident.

As awareness of the importance of the human factor in shipping has grown, recognition of the role of fatigue in maritime safety has also increased. There have been a number of high-profile and often costly and damaging casualties in which seafarer fatigue has been shown as a key causal factor. These include:



- the **Exxon Valdez** tanker disaster in 1989. The US National Transportation Safety Board found that in the 24 hours prior to the grounding of the ship, the watchkeeper had only had five or six hours of sleep
- the grounding of the general cargoship **Jambo** in Scotland in June 2003, after the chief officer fell asleep and missed an intended change of course
- the grounding of the bulk carrier **Pasha Bulker** near the port of Newcastle in Australia in June 2007, in which an investigation report stated that 'the master became increasingly overloaded, and affected by fatigue and anxiety'



- the grounding of the feeder containership **Cita** in the Isles of Scilly in March 1997, after the mate fell asleep and the ship sailed for two and a half hours with no one in control
- the death of a Filipino AB in a fall onboard the Danish-flagged general cargo ship **Thor Gitta** in May 2009. Investigators who used FAID fatigue assessment software found that the

seafarer's 6-on/6-off work pattern was at a score of 111 on the morning before to the accident – a level considered to be in the very high range

- the grounding of the bulk carrier **Shen Neng 1** on the Great Barrier Reef in April 2010. The Australian Transport Safety Bureau investigation found that the grounding occurred because the chief mate did not alter the ship's course at the designated position. His monitoring of the ship's position was ineffective and his actions were affected by fatigue. Investigations showed that he had only two and a half hours sleep in the 38.5 hours prior to the casualty.

Are there no controls on seafarers' working hours?

Under International Labour Organisation regulations (social provisions) it is permissible for seafarers to work up to 91 hours a week – and, under the International Maritime Organisation's Standards of Training, Certification & Watchkeeping (STCW) 2010 amendments (safety provisions), a 98-hour working week is allowed for up to two weeks in 'exceptional' circumstances.

The 2010 'Manila Amendments' require a minimum of 77 rest hours in any seven-day period. The hours of rest may be divided into no more than two periods per day, one of which shall be at least six hours in length, and the intervals between consecutive periods of rest shall not exceed 14 hours. Exceptions to the requirements are permitted in the case of an emergency or in other over-riding operational conditions. A party to STCW (usually the administration of the flag state) may also allow exceptions from the required hours of rest provided that the rest period is not less than 70 hours in any seven-day period – and these exceptions cannot be permitted to extend for more than two consecutive weeks. The intervals between two periods of such exceptions shall not be less than twice the duration of the exception.

How was the Project Horizon research carried out?

Project Horizon research was based on very rigorous scientific principles, involving unprecedented and cutting-edge use of deck, engine and cargo handling simulators to create realistic seven-day simulated voyage scenarios for the volunteer officers. The voyage plans were designed to ensure a high degree of authenticity, including variable workloads, port visits, changes of orders, mandatory reporting points, and passing traffic.



Who took part in the research?

A total of 90 officers were recruited to undertake the simulated voyages. All those taking part were appropriately qualified and experienced deck and engineer officers from west and east Europe, Africa and Asia. The mix of nationalities and gender (87 men and three women) provided a representative cross-section from the industry and all participants were required to be in good health, with no sleep disorders. The volunteers were recruited through advertisements and crewing agencies as if they were going to sea and during the tests they lived as close to a shipboard life as possible – in institutional-style cabin accommodation at WMA and onboard an accommodation vessel at Chalmers. During the runs, there were a number of imposed restrictions and participants were allowed up to four cups of coffee a day, with no alcohol permitted.

What were their working hours?

Project Horizon aimed to examine the effects of working two of the most common watchkeeping patterns – six hours on, six hours off and four hours on, eight hours off. To reflect real-life conditions – such as port calls, drills and emergencies – part of the study involved an interrupted off-watch period.

The total time spent 'working' during the week-long simulator runs was 64 hours for those on 4-on/8-off and 90 hours for 6-on/6-off participants (including the interrupted off-watch period). In one set of experiments, participants were randomly assigned to a watch system and a simulator and were told in advance that one of their off-watch periods would be interrupted – although they were not told which one it would be. During the interrupted off-watch, participants were supervised and had to undertake a mix of cargo operations simulator work and 'paperwork', including reading and watching the TV. They were not allowed to sleep during this period. This element of the programme was introduced to simulate real-world conditions, in which work patterns may be interrupted by such factors as port visits, inspections, cargo work, drills and emergencies. To balance the experiment design, one watch system had this disturbed off-watch period in the first part of the week, and the

second session with the same watch system had it in the second part of the week.

How were the research results obtained?

Data on participants' alertness and sleepiness was amassed using both subjective and objective research methods, including activity measurement devices (Actiwatches), computer-based vigilance and performance tests, and electrodes to record brain activity. The subjective information was drawn from the three diaries participants were asked to keep: a sleep diary filled in on waking up; a work diary they completed during the watch; and a wake diary completed during the off-watch period while awake.

In the watch diary, participants indicated how they felt at various points on duty using the Karolinska Sleepiness Scale. This scientifically validated measure ranges from 1 for 'extremely alert' to 9 for 'very sleepy, great effort to keep awake, fighting sleep'. This scale is validated against performance and EEG data in many studies. Dangerous levels start between 7 and 9 on the scale.

At two stages of the 'voyage', the participants wore 10 electrodes that measured their brain activity, over two watch periods and two sleep periods. Data obtained enabled the research teams to analyse whether crew fell asleep during their watchkeeping work and were unable perform any key tasks.

At Chalmers, navigation simulations were carried out using two different watch schedules: 30 seafarers were assessed over 4-on/8-off schedules, and 20 were monitored on 6-on/6-off patterns. The voyage pattern was based on a simulated voyage in a small coaster and cargo simulations replicating a 210,000dwt VLCC. The data gained from these different patterns were analysed separately. The two-watch runs also included a section involving the disturbance of a single free watch, in which no sleep was allowed to enable the investigation of the effect of additional workloads arising from a port visit.

At Warsash, bridge and engine room simulators were used to investigate the effects of 6-on/6-off work patterns. Cargo handling simulations were carried out at both locations. The Warsash run was undisturbed in order to evaluate 'time at sea' effects.

At Warsash, the simulators were linked up, so that the participants sailed a 17,071dwt product tanker from Fawley to Rotterdam and back again, twice, with a varied workload including cargo loading and discharge, and picking up and disembarking pilots.

In order to vary vigilance and workload levels, the simulations included some 'distinctly boring' sections as well as a number of realistic events and activities, including:



- **keeping the ship's logbook**
- **marking positions on a chart**
- **exchanging information at the end of a watch**
- **radio communications**
- **close-quarters situations with non-compliant vessels**
- **crossing, overtaking and fishing vessels**
- **a 'man overboard' from another ship**
- **a gyro-compass error**
- **monitoring of main and auxiliary machinery**
- **machinery alarms and technical breakdowns.**

Using simulators allowed the researchers to 're-set' the voyage at the end of each watch, so that the watchkeeper coming on duty repeated the section of the voyage just completed by the previous participant. As 'handovers' were conducted by staff members acting in the role of master or chief engineer, and other crew members, the participants were unaware that the voyage sections were being repeated in this manner. The standard test conditions and replicated situations enabled the researchers to make valid comparisons, under statistically robust conditions, monitoring the way in which the volunteer officers reacted and how their judgement and performance were affected at different times during the week.

Volunteers' performance was also checked by a wide range of indicators – with lecturers monitoring such things as their communications, behaviour, body language and ability to pass on 10 standard items of information at each watch handover.

During each bridge watch, participants were observed and rated by the simulator operators. The scoring system covered the general performance over the whole watch, the watch handovers, 'special' events – such as certain close-quarters situations – and 'unplanned' events – such as unintentional 'near-misses' with other vessels. The evaluation of watchkeeping performance was based on both expert rating (for example, how well the collision prevention regulations were followed) and objective scores (for

Research results

example, the number and timing of positions marked on the chart). Similar scoring of 'events' took place in the engine and cargo control room simulators.

Was the research a success?

Project Horizon has undoubtedly succeeded in its core aim of delivering a more informed and scientifically rigorous understanding of the way different watchkeeping patterns at sea affect the performance of ships' officers. The range of measurements and the high degree of realism gained through the use of simulators has provided detailed and robust data on which to assess and analyse effects. Data gained from the research is sufficiently robust to provide input to marine-validated mathematical fatigue prediction models within a fatigue risk management system.

Did the participants fall asleep?

Yes. In all four of the watchkeeping sub-groups (4/8 and 6/6 at Chalmers and 6/6 deck and engineers at Warsash) there was evidence of full-blown sleep. Incidents of sleep on watch mainly occurred during night and early morning watches. At least one incident of microsleep was detected among 40% of team 1, 4/8, at Chalmers (the 0000-0400 watch), around 45% of team 1, 6/6, at Chalmers (0000-0600 watch) and around 40% for team 2, 6/6, at Chalmers (0600-1200 watch). At Warsash the rates varied from more than 20% of the 1800-0000 watch to 0% of the 0600-1200 watch. Falling asleep on the bridge is a main indicator of the effect of the watch on dangerous states of the crew. Participants in all the groups reported high levels of subjective sleepiness on the KSS scale, close to danger levels for car drivers.

Did the participants obtain enough sleep?

No. Varying degrees of sleep loss were observed, differing between the watch systems. Overall sleep duration for those on

the 4/8 pattern was found to be relatively normal, with around 7.5 hours a day for those in team 1 at Chalmers and about 6 hours for team 2. Participants working 6/6 watches on 6/6 rotas were found to get markedly less sleep than those on 4/8, and data showed a clear 'split' sleeping pattern in which daily sleep on the 6/6 pattern was divided into two periods – one of between three to four hours and the other averaging between two to three hours.

Was performance affected?

Yes. PVT reaction time tests, carried out at the start and end of each watch showed clear evidence of a deterioration – the slowest reaction times were found at the end of night watches and among those on the 6/6 patterns.

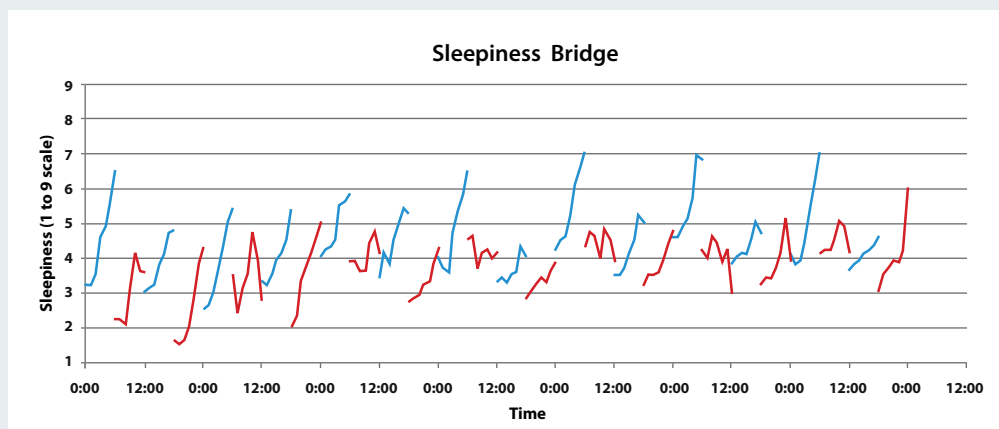
Watchkeepers were found to be most tired at night and in the afternoon, and sleepiness levels were found to peak towards the end of night watches. The 6/6 regime was found to be more tiring than the 4/8 rotas and the 'disturbed' off-watch periods were found to produce significantly high levels of tiredness.

In both watch systems the disturbed off-watch period was found to have a profound effect upon levels of sleepiness.

Overall, stress levels remained fairly low and did not differ significantly between the two watch systems. However, the disturbed off-watch period resulted in an immediate increase in stress levels.

Researchers noted limited variations in whole watch performance during the simulated voyages, although reduced performance on sustained attention tasks was observed. There was evidence that routine and procedural tasks tended to be carried out with little or no degradation, whilst participants appeared to find it harder to deal with novel 'incidents' such as collision avoidance or technical failures as the 'voyages' progressed.

Supervisors also noted a decline in the quality of the information being given by participants at watch handovers.



KSS sleepiness scores for the Warsash participants working 6-on/6-off in the bridge simulators. The team working 00:00 to 06:00 and 12:00 to 18:00 is indicated in blue and the team working 06:00 to 12:00 and 18:00 to 00:00 is indicated in red



Where do things go from here?

Project Horizon has undoubtedly achieved its principal objective of gaining a deeper and more scientifically rigorous understanding of the way in which sleepiness affects watchkeepers at sea.

It was intended that the project results could be used to assist the development of 'best practice' standards and policies. Analysis and assessment of the findings has enabled researchers to develop a lasting legacy, in the form of a proposed fatigue management toolkit. This set of tools is intended to provide practical guidance for seafarers, shipowners and operators, port state and flag authorities, regulators and other relevant bodies covering:

- the nature of fatigue or sleepiness at sea
- pointers to aid recognition of such conditions
- measures by which mitigation of them might be achieved
- concrete indications how the conditions might be avoided at source and the findings of the project might be applied

Why is a fatigue management toolkit needed?

It is recognised that shipping differs from some other transport modes in that the nature of risk exposure and the capacity to act is extremely variable. Data from Project Horizon indicates that the probability of danger at sea will be highest when night watches are combined with prior reduction of sleep opportunities, combined with passages through narrow or very densely travelled waters, or during reduced visibility.

The Project Horizon findings suggest that owners, regulators, seafarers and others should pay special attention to the potential risks in difficult waters in combination with the 6/6 watch system (because of sleep loss), night watches, the last portion of most watches (especially night watches), and watches after reduced sleep opportunity.

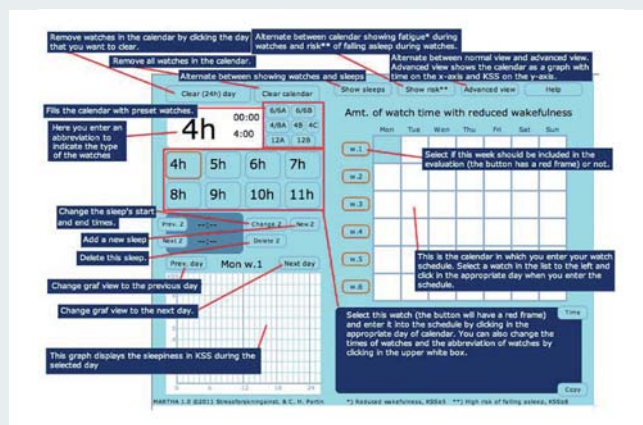
A variety of methods (some of which are already commonly deployed) may be used to address this potential risk, including alarm systems to alert crew before important waypoints, encouragement not to use chairs on the bridge during night watches, additional crew, training crew to recognise symptoms of fatigue, and special protection of sleep periods for watchkeepers.

The toolkit takes these precautions a step further, by using scientifically verified data to build mathematical models which can be used to predict which portions of a particular voyage may be critical from a fatigue point of view -- allowing mitigating action to be planned ahead of time.

How will a fatigue management toolkit work?

It is well known that working hours which deviate from conventional patterns (shift work, roster work, and irregular watch schedules) always entail a high probability of reduced sleep and of increased fatigue, with an ensuing accident risk. In recent years, scientists have developed mathematical models for alertness or performance prediction – and these have most notably been applied in the aviation industry. The Project Horizon researchers have used the results of their work to develop a maritime alertness regulation version of these models – 'MARTHA'.

The computer-based system will provide an interface with selectable watch schedules and a 'do-it-yourself' watch system facility. Users will be able to enter their working schedules over a six-week time window and receive predicted estimates of the most risky times and the times of highest potential sleepiness for each watch and for the whole watch schedule, as well as for time outside watch duty.



The major display contains estimates for each 24-hour period, with a second display to describe each 24-hour period with sleep periods and a continuous estimate of sleepiness. This information may also be displayed as miniatures in the main display.

MARTHA could be used onboard during voyage planning to develop watch systems that are efficient and that minimise risk. Shipping companies can use the system when planning voyage schedules and the size of the crew. The tool could also yield important International Safety Management Code benefits, as part of Fatigue Risk Management Systems (FRMS) and might be used for insurance and classification purposes.

MARTHA could also assist flag states and port state control authorities, enabling solid documentation if, for example, a ship is to be detained in order to let the crew rest before the voyage is resumed. It could also be used for the prevention and investigation of accidents.



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Stockholms Universitet – Stress Research Institute (SRI)

Charles Taylor & Co – The Standard P&I Club (CTPI)

European Community Shipowners Associations (ECSA)

European Harbour Masters Committee (EHMC)

International Association of Independent Tanker Owners – Intertanko (INTKO)

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